Cloth Manipulation and Perception Competition

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***Abstract*— In the last decade, several competitions in robotic manipulation have been organised as a way to drive scientific progress in the field. They enable comparison of different approaches through a well-defined benchmark with equal test conditions. However, current competitions usually focus on rigid-object manipulation, leaving behind the challenges that suppose grasping deformable objects, especially highly-deformable ones as cloth-like objects. In this paper, we want to present the first competition in perception and manipulation of textile objects as an efficient method to accelerate scientific progress in the domain of domestic service robots. To do so, we selected a small set of tasks to benchmark in a common framework using the same set of objects and assessment methods. This competition has been conceived to freely distribute the Household Cloth Object Set to research groups working on cloth manipulation and perception and participate on the challenge. In this work, we present an overview of the tasks that are proposed in the competition, detailed descriptions of the tasks and more information on the scoring and rules are provided in the website `http://www.iri.upc.edu/groups/perception/ClothManipulationChallenge/`.**

I. INTRODUCTION

Establishing well-defined benchmarks that serves to evaluate different robotic manipulations strategies across research groups in a standard manner is still a pending challenge in robotics. Several initiatives of benchmarks for grasping and manipulation have been proposed in recent years, including the definition of standard object sets such as the well-known YCB Object Set [1], which goal was to facilitate the fair comparison of approaches among the community of manipulation research. However, a benchmark is successful when it is widely accepted and used by the community at which it is targeted, what is difficult since applying benchmarking protocols is a thorough and time-consuming process and current benchmarks are usually too specific for the tackled task. The best practice to reach this acceptance within a scientific community is to arise the benchmark from the community itself. For this reason, the approach chosen by the authors of the YCB object set to let others know about their set was to distribute several of them at a series of tutorials at robotic conferences. Another good approach to reach acceptance is to get active participation through the organisation of robotic competitions.

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Similarly to the approach followed by the YCB authors, the motivation of the presented competition is to distribute the Household Cloth Object Set [2] among research groups working on the field. In addition, we want to bring together researchers in a common setup using these objects to benchmark the performance of autonomous manipulation and perception solutions involving textile objects across household applications. This object set was created as an extension of the YCB object set targeting textile objects to foster benchmarking in textile manipulation and therefore support progress in this field, what can further push towards developing service robots that can operate in unstructured human environments.

Our objective is to attract the participation of both perception and manipulation groups working with cloth-like objects. For this reason, the tasks that participants will tackle are divided into two tracks; (1) perception and (2) manipulation. Teams will be able to participate on one or several of the tasks, since together form a complete pipeline. This competition is aimed to be held as part of the Service Track of the Robotic Grasping and Manipulation Competition [3] that will take place at the next IROS 2022, in order to increase reachability and ease the participation of teams. We believe that putting efforts on defining test conditions that can be replicated at any robotic lab seems a reasonable approach to enhance reproducibility and comparability of results in robotics in the near future.

Based on the current challenges in manipulation of deformable objects, we selected a small set of tasks that include problems that have already been tackled in literature but that still require efforts to be considered as solved problems, for example grasp point detection [4–6] and folding of clothes [6–8]. With this competition we provide the first attempt of comparing current research approaches in perception and manipulation under the same test conditions in regards of objects used and assessment measures, providing relevant results in benchmarking cloth manipulation.

Our objectives are twofold:

- To organize a robotic competition focusing on the perception and manipulation challenges of highly deformable objects such as textiles to bring together research groups in a common framework.
- To distribute of the Household Cloth Object Set to research groups of the field to set the grounds on using common objects to foster benchmarking in manipulation of textiles.

II. Related work

A. Robotic manipulation competitions

Due to their potential to accelerate research activities effectively, several challenge programs have been organised in the past years focusing on manipulation of objects in realistic applications as industrial or service scenarios. Some of the more popular are the Amazon Picking Challenge [9], the RoboCub@Home [10] or the ARM project of DARPA. Nevertheless, these competitions are usually focused on manipulation of rigid objects, lacking a wide range of deformable objects, specially cloth-like objects, that suppose an increase on the challenges to solve. To the best of our knowledge, there has been no textile perception and manipulation competitions. This can be due to the high complexity that suppose highly deformable objects since it breaks fundamental assumptions in robotics such as rigidity, low-dimensional state space and known dynamic models. Regarding benchmarking, in similar way as with competitions, we find very few works that have attempted to define a benchmark focused on cloth manipulation. A recent work is presented in [11], where benchmarks for three bimanual cloth manipulation tasks are presented.

B. Challenges in deformable object manipulation

During the past years, several surveys [12–14] have collected the main challenges that appear according to the different components of which manipulation systems is composed, such as sensing, control, modelling or gripper design. Most of these surveys considers state estimation of deformable objects as one of the most important challenges, specially when tackling cloth-like objects due to the problems in dealing with self-occlusions and generating meaningful representation of their configurations. Many of the works that described approaches to deal with this issue [6, 7, 15] rely on holding the garment in the air to recognise the garment's configuration. However, before grasping the fabric it is first necessary to locate suitable grasping points. This is considered another challenge in perception, finding several works that used different perception techniques to solve it according to the cloth state and manipulation goal [4, 6, 16, 17]. Regarding grasping and manipulation, the most common identified challenges rely on the capabilities of precision in grasping, so that the robot is capable of firmly grasp single layers of a cloth before it bends under the contact of the gripper itself. This issue has been currently dealt in some works with the design of custom grippers [18] that reduce the need for precision. Another issue comes from the fact that, in contrast to rigid object manipulation where planners generate motions that avoid contacts, in textile manipulation is usually quite indispensable to consider contacts with the environment in order to properly grasp the fabric in many configurations, for example to grasp a flat cloth that lays on a table [8, 19]. In addition, in order to properly manipulate an object it is necessary to plan a sequence of manipulations that brings the cloth into the desired configurations, what is also a challenging problem mainly due to the difficulty in reasoning about a deformable object at a semantic level. A recent research [20] have worked on a way to represent states of cloth in a compact manner in order to enable clear representations of cloth manipulation tasks for planning purposes.

III. Competition description

In this section we present an overview of the proposed tasks for the competition, which have been selected based on the current trends and challenges in textile manipulation and perception. More information regarding the organisation, instructions on how to register to participate and competition dates is available in the related website [1], as well as detailed descriptions on the scoring and rules of each task.

The present competition is comprised of two tracks; (1) perception and (2) manipulation. On one hand, the first track is composed of a task which solution provides the main perception skills necessary to manipulate clothes. Depending on the methodology used to solve the task, several perception challenges can be solved, including cloth segmentation, state recognition or feature detection. On the other hand, the manipulation track includes two of the most common cloth manipulation tasks, which require of basic manipulation skills to perform them. Some of the manipulation challenges to be solved to perform these tasks includes precision in the grasping, plan the approach to the cloth so it does not deform before it is grasped correctly, possibility of environmental contact (in cases where the corner is touching the table), etc.

We consider a common setup for all the tasks. The objects that will be used are part of the household cloth object set, having objects of different sizes, colors and textures. In addition, a table of minimum dimensions will be necessary to perform the tasks. We do not restrict the characteristics of the table, but any necessary considerations (e.g. specific color of the table) will have to be reported. Any perception system can be used, but a bonus scoring will be added for those perception systems which are part of a robotic system (e.g. camera placed on the head of a mobile manipulator or included in a robotic arm). In similar way, any robotic system with grasping capabilities can be used in the tasks of the manipulation track. This includes no restrictions on the gripper hardware, being able to use custom design grippers that ease the manipulation of textiles.

A. Perception Track

Before being able to grasp an object it is first necessary to perceive it and locate a suitable grasping point. This is done by sensing the environment, usually with vision systems to obtain global information. We propose this task, where we want to assess not only the ability of detecting the corners and edges of the cloth but also the correct selection of grasping points according to the cloth configuration.

[1] http://www.iri.upc.edu/groups/perception/ClothManipulationChallenge/

*1) **Task 1.1. Grasp point detection**:* This task consists on selecting a suitable grasping point on a cloth that can be either crumpled, folded or flat on a table. The selected point must correspond to a graspable corner of a single layer of the cloth, providing the necessary information, such as coordinates and approach direction vector. To do so, it is necessary to first detect their relevant features as the corners and edges.

Steps:

1) Place the cloth on top of the table. Follow the protocol guidelines to place them in the indicated configuration.
2) Start the perception system.
3) Record the input images and point cloud clearly marking the selected point and the detected edges and corners.
4) Repeat steps 1 to 3 three times changing the object and its configuration.

Rules and Evaluation: The assessment of this task will consist on the correct selection of a suitable grasping point. To do so, it will be necessary to provide the results of the detected features of the cloth (edges and corners) and the coordinates of the grasping point, as well as the approach vector. The total execution time will be also taken into account in order to limit it to a reasonable time. Notice that as this task is aimed to assess the perception capabilities, during the competition the objects must be used in its original form, not being allowed to modify their properties in any way or add any type of markers that ease the perception.

B. Manipulation Track

This track focuses on the manipulation skills for textiles. The tasks of this track are based on two cloth manipulation tasks that are most studied in literature [21]; folding and unfolding. These two tasks include several manipulation skills present in many other cloth manipulation tasks. Both tasks can be performed and evaluated independently but teams are encourage to execute them continuously, completing the end-to-end pipeline, by adding a bonus scoring.

Since some perception skills are also necessary for this track, although they are not the object of evaluation, we offer the possibility of simplifying it by using some markers on the cloth (e.g. dying relevant parts as corners and edges). Nevertheless, a bonus score will be added to those strategies that do not need this help and perform the tasks using the cloth objects in its original form.

*1) **Task 2.1. Unfolding**:* This task consists on grasping the cloth and manipulating it until it is placed flat on the table. The cloth initial configuration can be either crumpled or folded and the final configuration of the task is flat. This task can be performed in many different ways, having no limitations on the strategies used. That is to say, it can be performed for example with a bimanual robotic system by grasping directly the corners, performing edge tracing to the second corner or by pushing and sliding the cloth on the table until it is flat. However, the evaluation will take into account several parameters as the total execution time or the number of state transitions performed since the task starts.

Steps:

1) Place the cloth in the indicated configuration, either folded or crumpled. Follow the configuration protocol to set them correclty.
2) Start the execution of the task and start the timer.
3) Save the result by taking a zenithal picture of the flat cloth.
4) Repeat steps 1 to 3 five times, changing at each trial the object and its configuration.

Rules and Evaluation: This task will be considered successful when the cloth has been placed laying flat and is completely inside of the table. The quality of the placement will be evaluated by measuring the resulting area of the cloth and computing the error with respect to a predefined template. In addition, the total execution time and the number of state transitions [20] (i.e. changes in the grasp location, grasp type or cloth configuration) will also be taken into account. The task ends when the cloth is placed flat on the table or when the maximum execution time is exceeded.

*2) **Task 2.2. Folding**:* The last task of the track consists on folding the cloth two times once is flat on the table. In order to correctly perform this task, the object must be folded following the folding protocol.

This task can be a continuation of Task 2.1, being able to execute it in sequence right after the previous one, performing an end-to-end pipeline of the whole task of folding a cloth starting from a crumpled configuration.

Steps:

1) Place the object flat in the table and place the robotic system in a form that the cloth is inside its reachability.
2) Start the task execution and the timer.
3) Save the result by taking a zenithal picture of the folded cloth.
4) Perform five trials repeating steps 1 to 3, changing the object.

Rules and evaluation: A single fold is considered successful when the opposing corners are together. The task is considered successfully completed when the two folds are performed according to the protocol. In similar way to Task 2.1, the quality of the result will be evaluated by comparing the final area of the folded cloth with the expected area, which for the case of two folds will be 1/4 of the total area of the flat cloth. Take into account that in order to avoid over-engineering of the solution, the day of the competition the organisers may indicate to change a bit the initial position of the flat cloth by rotating or moving it over the table.

IV. Conclusions

We propose the first competition in manipulation and perception of highly deformable objects, such as textiles, with a compromise between tasks that can be implemented by most of current research groups but that offer challenges to be considered as fully solved. We believe that the organisation of this kind of competition is a great way to improve and compare state-of-the-art approaches and that will provide usefull knowledge for the deformable object manipulation community.

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